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Abstract

PROSPECTIVE D_2O-MODERATED POWER REACTORS

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1. Capital-cost estimates for very high power reactors of several hundred up to 1000 megawatts (electrical) indicate that many types would be competitive. In each case, however, an optimum technical design must be sought. Cool heavy water offers several advantages as moderator; not only does it improve neutron economy but it also aids containment and pressure suppression in the event of a major leak of high-temperature water or steam. The hot fuel channel may be insulated from the cool moderator by a gas gap between a hot pressure tube and a cold "calandria" tube. Alternatively, the stress tube may be cooled and carry solid internal insulation with a thin metal liner. Zirconium alloys have proved supreme for these tubes and may be further developed for strength and corrosion resistance. One possible heat-transport fluid or caloporteur would be a radiation-resistant organic liquid, such as terphenyl. For this fluid aluminum or SAP (an aluminum-alumina sinter) offer some advantages. Liquid D_2O is an established caloporteur of continuing promise; also either D_2O or H_2O may be used as a two-phase steam-liquid mixture. A minimum volume of caloporteur is required for several reasons: to preserve neutron economy, minimize reactivity changes arising from density changes or voiding, and to minimize the stored energy and in the case of the organic to minimize radiolytic decomposition.

2. In the long-term future, most fission energy from thermal-neutron reactors seems likely to be derived from thorium via uranium-233. For the next several decades, however, natural uranium appears most promising and economical. Enriched uranium has been included in the studies.

3. Preselection of reactor types led to detailed optimization and costing evaluations of reactors of large capacity using the caloporteurs mentioned. Fuels of various configurations and, in management, schemes allowing axial and radial flux flattening were evaluated. UO_2, UC and possible U metal alloys were considered where applicable.

4. The general method of assessment was to establish an electronic-computer program in which nuclear data, materials properties and costing information would be combined to yield optimum costs without transgressing selected limits of flow velocities, temperatures, stresses and other conditions. Several hundred reactors have been evaluated in this manner. From these results promising "reference" designs were chosen for each selected caloporteur. Preliminary mechanical designs were made for each reference case, and capital-cost estimates were made from these designs and fed back into the power-cost evaluation.

5. The general conclusion is that the greatest power-cost reductions will come from increasing the capacity of each reactor and of the complete plant. Beyond this, the major cost reductions follow from improved neutron economy by the use of thin-walled tubing and of dense fuel and from improved thermal-to-electric conversion efficiency by raising the mean temperature of the caloporteur. Significant reductions would also result from the expected further lowering of the cost of heavy water, and from improved construction methods. The use of thorium fuel does not appear favourable unless ^{235}U becomes available at less than \$12/g or the cost of natural uranium rises above about \$40/kg U.